CHAPTER 45
Aortic Regurgitation

KEY TEACHING POINTS

- The characteristic murmur of *chronic* aortic regurgitation is blowing, early diastolic, and decrescendo in shape. It is heard best with the diaphragm of the stethoscope positioned near the lower left sternal edge and with the patient sitting up, leaning forward, and holding his or her breath in exhalation.
- The *presence* of this characteristic murmur greatly increases probability of aortic regurgitation; its *absence* is a compelling argument *against* regurgitation of moderate-to-severe degree.
- In patients with the characteristic murmur of chronic aortic regurgitation, the following findings increase probability of moderate-to-severe regurgitation: diastolic blood pressure less than or equal to 50 mm Hg and pulse pressure greater than or equal to 80 mm Hg. A diastolic blood pressure greater than 70 mm Hg and pulse pressure less than 60 mg *decrease* probability of moderate-to-severe regurgitation.
- In comparison to chronic aortic regurgitation, the murmur of *acute* aortic regurgitation (e.g., from endocarditis or acute aortic dissection) is often shorter and more likely to be associated with tachycardia, hypotension, and narrow pulse pressure.

I. INTRODUCTION

The principal problem in aortic regurgitation is defective closure of the aortic valve, which allows blood to return from the aorta to the left ventricle during diastole. In patients with significant chronic regurgitation, the traditional physical findings are a diastolic murmur, dilated apical impulse, and abnormally forceful and collapsing arterial pulses (pulsus celer).

In the 1700s clinicians associated the postmortem finding of damaged aortic valves with hearts "larger than that of an ordinary ox" (the origin of the phrase *cor bovinum*) and the finding during life of "violently throbbing" carotid arteries. In 1832 Sir Dominic John Corrigan, a Dublin surgeon, taught clinicians how to diagnose the disease during life, by emphasizing the importance of these dramatic arterial pulsations and the associated diastolic murmur.[1,2]

II. THE FINDINGS

A. THE MURMUR(S)

Severe aortic regurgitation may cause three distinct murmurs: (1) the early diastolic murmur of aortic regurgitation, (2) a systolic aortic flow murmur, and (3) the apical diastolic rumble of the Austin Flint murmur.

1. EARLY DIASTOLIC MURMUR OF REGURGITATION

The most important physical sign of aortic regurgitation is the early diastolic murmur, which is blowing, high frequency, and decrescendo in shape (see Chapter 43).

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The murmur may occupy all of diastole or only its early part.[3] Pressing firmly against the chest wall with the diaphragm of the stethoscope brings out the murmur, which is usually loudest in the left parasternal area at the third or fourth intercostal space. In some patients the murmur is audible only when the patient sits up, leans forward, and holds his or her breath in exhalation.

2. SYSTOLIC AORTIC FLOW MURMUR

Severe aortic regurgitation also produces a short systolic aortic flow murmur, which results from ejection over the aortic valve of the large stroke volume characteristic of the disease. The combination of this murmur and the early diastolic one causes a characteristic "to-fro" sound near the sternum (see Chapter 43).

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This murmur may superficially resemble that of aortic stenosis, although the flow murmur of pure regurgitation is shorter and associated with the peripheral pulse findings of severe regurgitation (see later).

3. APICAL DIASTOLIC RUMBLE: AUSTIN FLINT MURMUR

A. DEFINITION

The Austin Flint murmur is a diastolic rumbling murmur heard at the apex in patients with severe aortic regurgitation, which resembles mitral stenosis even though the mitral valve is completely normal. It was first described by the American physician Austin Flint in 1862.[4]

The Austin Flint murmur is found in up to 60% of patients with moderate or severe aortic regurgitation but is rarely heard in mild aortic regurgitation.[5,6] Austin Flint called his murmur *presystolic*, but by this he meant it was loudest before S_1 and thus different from the murmur of aortic regurgitation, which began immediately after S_2 and tapered off during diastole. Approximately half of Austin Flint murmurs have two diastolic components (mid-diastolic and presystolic), whereas the other half have just a presystolic component.[6,7]

B. PATHOGENESIS

The cause of the Austin Flint murmur is still debated. Although all hypotheses assume the murmur depends on a strong regurgitant stream of blood being directed back toward the left ventricle during diastole, these hypotheses differ in how this regurgitant stream causes an apical rumbling sound. Proposed mechanisms include fluttering of the anterior leaflet of the mitral valve, premature closure of the mitral valve from elevated left ventricular end-diastolic pressure, collision of the regurgitant stream with the anterior mitral leaflet, ventricular vibrations caused by the regurgitant stream itself, and harmonic distortion of the aortic regurgitant murmur.[6,8,9] Many of these mechanisms may operate together to create the sound.[10] An instructive video showing the blood flow responsible for the Austin Flint murmur is available in reference by Weir.[11]

B. WATER HAMMER PULSE AND INCREASED PULSE PRESSURE

Because of the large stroke volume and diastolic emptying of aortic blood into the left ventricle (i.e., aortic runoff), the arterial pulse wave of aortic regurgitation rises suddenly and collapses abruptly. This abnormality has many names, although

the most common ones are **collapsing pulse**, **Corrigan pulse**, or the **water hammer pulse.*** In most patients with aortic regurgitation the collapsing pulse becomes more prominent as the examiner elevates the patient's wrist.[12,13] This occurs because elevation of the arm with respect to the heart reduces the diastolic pressure in that arm, causing the vessel to collapse more completely with each beat. (The pounding sensation of the water hammer pulse is identical to the sensation felt by the examiner when palpating a person's blood pressure, with the cuff pressure just above the person's diastolic pressure; see Chapter 17.)

C. ABNORMAL PULSATIONS OF OTHER STRUCTURES: THE AORTIC REGURGITATION EPONYMS

The large stroke volume and aortic runoff of aortic regurgitation may induce pulsations in other parts of the body, which has generated many eponyms of what is fundamentally a single physical finding (the number of eponyms for aortic regurgitation rivals those of some neurologic reflexes).[1,14-17] These various bobbings include the following: (1) an abnormally conspicuous capillary pulsation, best elicited by blanching a portion of the nail and then observing the pulsating border between the white and red color (**Quincke capillary pulsations**, described in 1868, although Heinrich Quincke should be known instead for inventing the lumbar puncture); (2) an anterior-posterior bobbing of the head, synchronous with the arterial pulsations (**de Musset sign**, named after the French poet Alfred de Musset, who was afflicted with aortic regurgitation);[18] (3) alternate blanching and flushing of the forehead and face (**lighthouse sign**); (4) pulsations of organs or their parts, including the uvula (**Müller sign**, 1899), retinal arteries (**Becker sign**), larynx (**Oliver-Cardarelli sign**), spleen (**Sailer sign**, 1928),[19] and cervix (**Dennison sign**).[20†]

In many of the original descriptions of these eponymous findings, the sign was presented simply as an interesting observation, not one of particular diagnostic value. Excellent videos of patients with bounding carotids,[21] Quincke pulse,[22] and Müller sign[23] are available.

D. HILL TEST

In 1909 Leonard Hill of Britain observed that patients with severe aortic regurgitation often have a systolic pressure in the foot that is much greater than a simultaneously measured systolic pressure in the arm.[24,25] The **Hill test** specifically refers to the systolic pressure of the foot minus that of the arm. The correct technique for measuring the pressure in the foot is to wrap the arm cuff around the patient's calf and to measure the systolic pressure in the dorsalis pedis and posterior tibial arteries by palpation. The higher of these two pressures is the "foot pressure."

E. AUSCULTATION OVER ARTERIES

Two auscultatory findings may appear over the peripheral arteries of patients with aortic regurgitation: **pistol shot sounds** and **Duroziez murmur** (or **Duroziez sign**).

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*Corrigan actually emphasized the exaggerated *visible* pulsations of aortic regurgitation, not the palpable ones. The term *water-hammer pulse* was coined in 1836 by Sir Thomas Watson, who likened the pulse to a Victorian toy called a water-hammer, which imparted to a child's hands the same sensation of a collapsing pulse of aortic regurgitation.[2]

†The eponym does not necessarily indicate priority: Sailor gave credit for the pulsating spleen to Tulp of the 1600s,[19] and Dennison gave credit for the pulsating cervix to Shelly, one of his house officers.[20]

1. PISTOL-SHOT SOUND

A. DEFINITION

Pistol shot sounds are short, loud, snapping sounds with each pulse, heard over the femoral, brachial, or radial arteries. They are identical in quality to the Korotkoff sounds heard when measuring blood pressure. Pistol shot sounds are heard with only *light* pressure of the stethoscope and, like the water hammer pulse, may first appear only after elevation of the patient's arm.[13]

Pistol shot sounds were first described by Traube in 1872.[26,27]

B. PATHOGENESIS

Pistol shot sounds occur because of sudden expansion and tensing of the walls of the vessels during systole. Consequently, they are not only associated with the collapsing pulses of aortic regurgitation but also are inducible in normal individuals by administering intravenous vasodilator medications.[28] The sounds are analogous to the loud, snapping notes heard when a sail or parachute suddenly fills with wind.[29] The quicker the vessel dilates, the louder the note, and in patients with aortic regurgitation, the intensity of the pistol-shot sound correlates with the height of the pulse pressure[30] and the change in pressure over time (dP/dT) of the pulse.[28]

2. DUROZIEZ MURMUR OR SIGN[14,26,31-34]

A. DEFINITION

The Duroziez sign is a *double* to-fro murmur heard over the brachial or femoral artery. It is heard only with *firm* pressure from the stethoscope. For the Duroziez sign to be positive, both a systolic and diastolic murmur must be present (many normal persons develop systolic murmurs with pressure on the stethoscope). The diastolic component often becomes louder with pressure applied distal to the stethoscope.

Although some claim the Duroziez murmur also may occur in normal individuals who have increased flow because of fever, anemia, or peripheral vasodilatation,[31] the vascular sound produced in these conditions does not have the characteristic to-fro sound of the Duroziez murmur but instead resemble the continuous murmur of an arteriovenous fistula.[33]

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Duroziez described his "double intermittent murmur" in 1861.[26,35]

B. PATHOGENESIS

The diastolic component of Duroziez sign results from the blood actually reversing directions in the artery during diastole.[32,33]

III. CLINICAL SIGNIFICANCE

A. DETECTING AORTIC INSUFFICIENCY

The presence of the characteristic early diastolic murmur of aortic insufficiency greatly increases the probability that an aortic leak is actually present (likelihood ratio [LR] = 9.9; EBM Box 45.1). Although some patients with mild regurgitation have no murmur, the *absence* of the characteristic murmur greatly *decreases* the probability of moderate-to-severe aortic regurgitation (LR = 0.1; see EBM Box 45.1).

EBM BOX 45.1
*Aortic Regurgitation**

Finding (Reference)	Sensitivity (%)	Specificity (%)	Likelihood Ratio† if Finding Is	
			Present	Absent
Characteristic Diastolic Murmur				
Detecting mild aortic regurgitation or worse[36-43]	54-87	75-98	**9.9**	**0.3**
Detecting moderate-to-severe aortic regurgitation[40-43]	88-98	52-88	**4.3**	**0.1**
Early Diastolic Murmur Loudest on Right Side of Sternum				
Detecting dilated aortic root or endocarditis[3]	29	96	**8.2**	0.7
Early Diastolic Murmur Softer With Amyl Nitrite Inhalation				
Detecting aortic regurgitation (vs. Graham Steell murmur)[44]	95	83	NS	**0.1**

*Diagnostic standard: For *moderate-to-severe aortic regurgitation*, see EBM Box 45.2.
†Likelihood ratio (LR) if finding present = positive LR; LR if finding absent = negative LR.
NS, Not significant.
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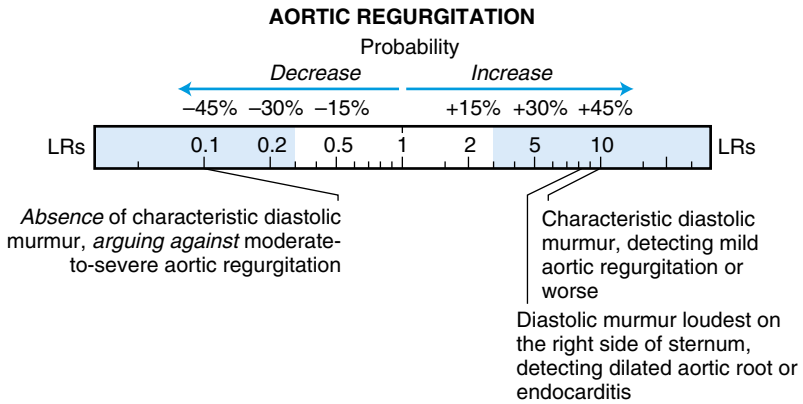

B. DISTINGUISHING AORTIC VALVE DISEASE FROM AORTIC ROOT DISEASE

The early diastolic murmur of aortic regurgitation is usually loudest in the left parasternal area. In some patients the murmur may be loudest to the right of the sternum, which suggests an eccentric regurgitant stream from dilation of the aortic root (e.g., Marfan syndrome, aortic dissection, syphilitic aortitis) or damage to a single aortic cusp (e.g., endocarditis). This sign, introduced by Harvey in 1963,[45] increases

the probability of a dilated root or endocarditis (LR = 8.2; see EBM Box 45.1); its absence is diagnostically unhelpful (LR = 0.7).‡

C. DISTINGUISHING AORTIC REGURGITATION FROM PULMONARY REGURGITATION

Distinguishing aortic from pulmonary regurgitation was particularly relevant in patients with rheumatic mitral stenosis, who often had associated aortic valve disease but who also could develop pulmonary hypertension and the early diastolic murmur of pulmonary insufficiency (i.e., the **Graham Steell murmur**).

In patients with mitral stenosis who also have an early diastolic murmur of regurgitation heard next to the sternum, the additional lesion is aortic regurgitation at least 80% of the time. Aortic regurgitation is the most common correct diagnosis even when there are no peripheral pulse findings of aortic regurgitation and the patient shows signs of severe pulmonary hypertension.[36,46,47] In the past, reducing afterload with amyl nitrite inhalation was used to distinguish aortic from pulmonary regurgitation because amyl nitrite should diminish the intensity of the aortic regurgitation murmur (i.e., less regurgitant flow) but not affect the pulmonary regurgitation murmur. The finding of an early diastolic murmur that instead becomes louder or does not change after amyl nitrite inhalation *decreases* the probability of aortic regurgitation (LR = 0.1; see EBM Box 45.1).

D. SEVERITY OF AORTIC REGURGITATION

This section applies only to patients with the characteristic early diastolic murmur of chronic aortic regurgitation (EBM Box 45.2). It does not apply to acute aortic regurgitation (see the section on Acute Aortic Regurgitation). Many of the patients enrolled in the studies also had additional murmurs of aortic stenosis or mitral regurgitation.

1. THE DIASTOLIC MURMUR

The louder the murmur, the more severe the aortic regurgitation (r = 0.67).[48] Murmurs of grade 3 or more indicate moderate-to-severe aortic regurgitation (LR = 8.2; see EBM Box 45.2).

2. BLOOD PRESSURE

Two findings *increasing* the probability of moderate-to-severe regurgitation in these patients are diastolic blood pressure of 50 mm Hg or less (LR = 19.3; see EBM Box 45.2) and pulse pressure of 80 mm Hg or more (LR = 10.9; see EBM Box 45.2). Two findings *decreasing* the probability of significant regurgitation are diastolic blood pressure of more than 70 mm Hg (LR = 0.2) and pulse pressure of less than 60 mm Hg (LR = 0.3). These signs have no diagnostic value when applied to other patients lacking the characteristic murmur of aortic regurgitation.[39]

3. HILL TEST

If the abnormal response in the Hill test is defined as a foot-arm blood pressure difference of 60 mm Hg or more, the positive test significantly increases the probability of significant regurgitation (LR = 17.3; see EBM Box 45.2).

‡The diagnostic accuracy of the "Harvey sign" is based on patients from the 1960s, when most patients with aortic insufficiency had either rheumatic valvular disease or syphilitic root disease. Whether it is as accurate today is unknown.

Some doubt that the Hill test is accurate, citing experiments showing the intra-arterial pressure in the *femoral arteries* of patients with aortic regurgitation to be identical to that of the brachial arteries.[51,52] However, the Hill test measures the pressure of the pedal arteries, not the femoral arteries. It is possible that the systolic pressure is augmented in the foot, which is near the point of reflection of the abnormal pulse waveform.

EBM BOX 45.2

*Characteristics of Moderate-to-Severe Aortic Regurgitation**

Finding (Reference)†	*Sensitivity (%)*	*Specificity (%)*	**Likelihood Ratio‡ if Finding Is**	
			Present	*Absent*
Diastolic Murmur				
Murmur grade 3 or louder[39,48]	30-61	86-98	**8.2**	0.6
Blood Pressure				
Diastolic Blood Pressure[36,49]				
>70 mm Hg	8-21	32-55	**0.2**	—
51-70 mm Hg	42-50	–	NS	—
≤50 mm Hg	30-50	98	**19.3**	—
Pulse Pressure[49]				
<60 mm Hg	21	32	**0.3**	—
60-79 mm Hg	21	–	NS	—
≥80 mm Hg	57	95	**10.9**	—
Hill Test				
Hill Test[49]				
<40 mm Hg	29	13	**0.3**	—
40-59 mm Hg	29	–	NS	—
≥60 mm Hg	42	98	**17.3**	—
Other Signs				
Enlarged or sustained apical impulse[49]	97	60	2.4	**0.1**
S_3 gallop[50]	20	97	**5.9**	0.8
Duroziez sign, femoral pistol shot, water hammer pulse[33,49]	37-55	63-98	NS	0.7

*Diagnostic standard: For *moderate-to-severe regurgitation,* regurgitation was either 3+ (moderate) or 4+ (severe) on a 0 to 4+ scale, using angiography,[36-38,42,43,49] Doppler echocardiography,[40,41,48,50] or surgery.[39] Trivial regurgitation on echocardiography was classified as "absent regurgitation."

†Definition of findings: see the text.

‡Likelihood ratio (LR) if finding present = positive LR; LR if finding absent = negative LR.

NS, Not significant.

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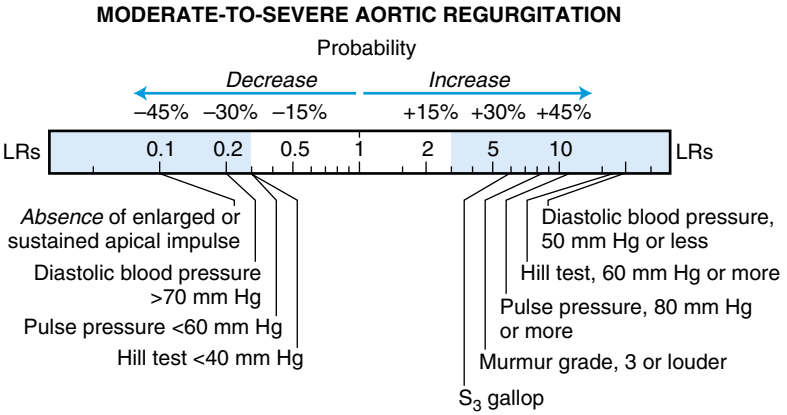

4. OTHER SIGNS

The *absence* of an enlarged or sustained apical impulse *decreases* the probability of moderate-to-severe regurgitation (LR = 0.1; see EBM Box 45.2).

In one study of patients with pure aortic regurgitation, the finding of a third heart sound increased the probability of severe regurgitation (LR = 5.9). Even so, the S_3 does not reliably indicate elevated left atrial pressure in these patients because regurgitation alone may accelerate early diastolic filling sufficiently to produce the sound (see Chapter 41).[53,54] The Duroziez sign, femoral pistol shots, and the water hammer pulse are all unreliable indicators of severity of regurgitation.

E. ACUTE AORTIC REGURGITATION

Compared with chronic aortic regurgitation, acute aortic regurgitation (e.g., from endocarditis or acute aortic dissection) causes a shorter murmur, faster pulse rate (108 beats/min vs. 71 beats/min, mean values), smaller pulse pressure (55 mm Hg vs. 105 mm Hg), and lower systolic blood pressure (110 mm Hg vs. 155 mm Hg).[55] The murmur of acute aortic regurgitation is shorter because the combination of low arterial pressure and very high ventricular filling pressure eliminates the pressure gradient causing regurgitation by mid-diastole.[55] The first heart sound is faint or absent in acute aortic regurgitation because of premature closure of the mitral valve (see Chapter 40).[56] In patients with aortic regurgitation from endocarditis, an associated pericardial rub often indicates extravalvular extension of the infection.[55]

F. DISTINGUISHING THE AUSTIN FLINT MURMUR FROM MITRAL STENOSIS

Based on an older analysis of 400 patients with severe aortic regurgitation, many of whom also had apical diastolic rumbles, the following findings increase the probability of associated mitral stenosis: atrial fibrillation, loud S_1, absent S_3, and opening snap. Findings suggesting that the apical rumble more likely is an Austin Flint murmur are sinus rhythm, faint S_1, S_3 gallop, and absent opening snap.[57] In addition, inhalation of amyl nitrite, which reduces systemic vascular resistance, makes the Austin Flint murmur (and the aortic regurgitation murmur) softer but the apical rumble of true mitral stenosis louder.[58]

The references for this chapter can be found on www.expertconsult.com.

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